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ABSTRACT

The feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and therefore reduce training time and increase personnel flexibility was investigated by the Office of Naval Research. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks but which had earlier been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The findings were discussed in relation to training regimens and the complexity of the criterion task. (The study also contains a list of references, examples of training tasks, and addresses of people on the distribution list.) (Author/CT)

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TRAINABILITY OF ABILITIES:
TRAINING AND TRANSFER OF ABILITIES RELATED TO ELECTRONIC FAULT-FINDING

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TECHNICAL REPORT

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The feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and therefore reduce training time and increase personnel flexibility was investigated. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks but which had earlier (cont'd)

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been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The findings were discussed in relation to training regimens and the complexity of the criterion task.

ABSTRACT

The feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and therefore reduce training time and increase personnel flexibility was investigated. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks but which had earlier been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The findings were discussed in relation to training regimens and the complexity of the criterion task.

INTRODUCTION

The need for more flexible and adaptable Navy personnel is receiving increased recognition. While training and selection for specific job assignments continue, there is a need for programs which will produce personnel capable of performing a broader range of Navy tasks and jobs. A number of factors contribute to this trend, including the possibilities of fewer billets and smaller crew sizes, and the increased complexity of Navy jobs and tasks. Additionally, the impact of automation in man-machine systems has been to enhance the responsibility of the reduced number of personnel manning and maintaining these systems. Increased flexibility and adaptability of personnel in shifting to different tasks can minimize disruption in system effectiveness and minimize retraining costs associated with attrition and reassignment problems.

The purpose of the present research was to examine the feasibility of training selected abilities so as to facilitate transfer among tasks requiring these abilities and, therefore, reduce training time and increase personnel flexibility. If abilities can be improved through the use of diversified and intensive training, then this improvement should generalize to a variety of tasks and jobs in which the abilities are involved. Ability training may provide a more efficient approach for training individuals to perform a variety of different tasks than training for each specific task.

The identification of human abilities accounting for individual differences in cognitive, perceptual, and motor aspects of human performance has been the subject of extensive research (cf. Fleishman, 1964,

1972; French, Eckstrom, & Price, 1963; and Guilford, 1967). Considerable investigative effort has resulted in the conceptualization of abilities as broad capacities underlying performance in complex skills and related to performance in a variety of human tasks (Fleishman, 1967a, 1972). Typically, abilities are identified through correlational studies of human task performance, in which the fact of individual differences is exploited to gain insights about common processes required to perform different groups of tasks. Thus, abilities are defined by empirically determined relations among observed separate performances. Skills are more specific, and define levels of proficiency in particular tasks. These skills can be described in terms of component abilities required to perform them, with certain abilities shown to underly performance in many superficially different human tasks. There is much information now available as to which abilities are required for the performance of a variety of tasks.

Fleishman and his associates have shown that abilities are related to the progress individuals make in learning new, more complex skills, and to the final levels they attain after given amounts of training in these skills (Fleishman, 1967b, 1972; Fleishman & Hempel, 1965, 1956; and Fleishman & Fruchter, 1960). Similar investigations examined the relationships between abilities and learning rates and a variety of other learning measures (Fleishman & Ellison, 1969; Fruchter & Fleishman, 1967). From this research, it appears that abilities are more general than specific skills, and that abilities relate to progress in learning and training.

The idea that human abilities can be improved through training is a practical notion receiving little direct investigation. Most abilities

are considered to be the product of earlier learning and genetic factors (Ferguson, 1956; Gagne & Fleishman, 1959), and are defined as relatively stable attributes in the adult (Fleishman, 1972). However, there is some evidence that certain abilities can be enhanced by diversified training. Kysor and Hart (1969) found practice to improve number facility. Brinkman (1966) provided extensive training in the behaviors thought to be involved in spatial visualization (i.e., discrimination, recognition, organization, and orientation), and found significant improvement, on a spatial relations criterion test administered before and after training, for the trained group but not for an untrained control group. Stringer (1975) attempted to enhance spatial ability using various drawing training procedures and found that trained groups did better than an untrained control group on a test of spatial relations, but only when there was content similarity between the training and testing materials.

There is little doubt that performance on a task can be enhanced by training on similar tasks. Postman (1971) has reviewed the extensive literature on the direct relationship between task similarity and transfer of training. The major concern of the present study, however, is whether or not the training of an ability using a variety of tasks and materials, which are relatively dissimilar to a criterion task can enhance performance on the criterion task. In order to demonstrate such a phenomenon, it is necessary to select training materials and criterion tasks which tap the identical ability, but which are otherwise dissimilar. In this fashion, any improvement which might result from training could not be attributed to the similarity between training and criterion tasks. Instead, improvement could be inferred to have resulted from the enhancement of the ability

through training and the positive transfer of this training to the criterion task.

A recently completed comprehensive review of the literature (Hogan, 1978) relevant to training abilities revealed no other controlled test of whether or not ability training can ultimately transfer positively to dissimilar tasks requiring the same abilities. The early work at the beginning of this century was most directly related to this issue, but was fraught with methodological difficulties which precluded conclusions from being drawn (see Postman, 1971).

There is evidence, however, from other areas of research employing transfer paradigms which suggests that "nonspecific" transfer does, in fact, take place. Research on learning to learn has reported positive transfer when there was only minimal similarity between training and criterion tasks (Duncan, 1953, 1958; Posner & Keele, 1968). Additional support comes from simulation efforts which demonstrate that highly generalized training simulators promote transfer to very specialized tasks. Further, educational researchers have reported modest success at training intellectual abilities (see, for example, Parnes & Noller, 1972; and Maltzman & Morrisett, 1952).

The present study was designed to determine (a) whether intensive training could result in the improvement of an ability, and (b) whether such an improvement would transfer to a task which was dissimilar to the training tasks, but which required the same ability for successful performance.

METHOD

The abilities selected for study were flexibility of closure and spatial scanning. Flexibility of closure is defined as the ability to identify or detect a known pattern (a figure, word, or object) which is hidden in background material. Spatial scanning is defined as speed in visually exploring a wide or complicated spatial field to detect or identify objects. The rationale for selecting these abilities was that (a) they did not involve highly learned or familiar types of behavior, (b) they could be represented by a wide variety of materials for training, and (c) they were dominant abilities in a laboratory task which simulated a Navy job. A diverse set of training materials was identified which had been shown to tap these abilities.

The criterion, or transfer task, was troubleshooting (electronic fault-finding). Previous research (Rose, Fingerman, Wheaton, Eisner, & Kramer, 1974) had indicated that flexibility of closure and spatial scanning were jointly the most important abilities in the task and that their importance increased with increasing problem difficulty. In that study twenty-one ability tests, hypothesized to contribute to performance on the troubleshooting task, were administered to a population of college students, who subsequently performed on the troubleshooting task. Flexibility of closure and spatial scanning together loaded approximately .30 on several measures of task performance. Other abilities related to performance included associative memory, syllogistic reasoning, and induction.

Subjects

Sixty undergraduate students from local universities served as subjects. They were volunteers and were paid approximately $3.00 per hour

for their participation. An additional performance-based monetary incentive was associated with all tasks which resulted in total earnings of from $4.50 to $5.00 per hour.

Training Tasks

The training paradigm was designed to provide subjects with structured practice in utilizing the abilities of flexibility of closure and spatial scanning. It consisted of a series of nine self-administered, paper-and-pencil tasks with built-in feedback. Six tasks were designed to train flexibility of closure; three to train spatial scanning. The tasks were either derived from or patterned after standard ability and aptitude tests or were judged to substantially involve the ability of interest. The Mental Measurements Yearbook (O. Buros, Ed.) was used as a source for aptitude tests which were known to measure the abilities being studied. This source also provided factor loadings and correlational data for many of these tests which were used to substantiate that we were, in fact, training the abilities that we intended to train. The Kit of Factor-Referenced Cognitive Tests was also used as a source of training tasks.

In selecting and developing training tasks, certain guidelines were adhered to in addition to the obvious one that the tasks provide the trainee with structured practice in applying the abilities. These were:

- Task difficulty level had to be great enough to challenge subjects and to promote learning.
- The tasks had to be diverse so that subjects would be given the opportunity to apply the abilities in a variety of contexts. This would enable individuals to develop a repertoire of strategies appropriate to

various situations--an important condition for the transfer of general abilities.

- Training materials and tasks had to be as dissimilar as possible from the criterion task, while still requiring use of the same abilities. This requirement reduced the possibility of transfer occurring as a result of task similarity rather than ability training per se.

The training tasks selected for use are described below. The Appendix provides examples of items from each of these tasks.

- Task 1 -- "Hidden Figures" (flexibility of closure)
  Subjects were presented with a series of five geometric figures and a complex design in which one of the figures was embedded. The task was to visually search the design and identify which figure was contained within it, at the same time outlining the embedded figure.
- Task 2 -- "Copying" (flexibility of closure)
  In this task subjects copied a series of asymmetrical line drawings, composed of connecting line segments, onto grids formed of dots. Subjects' drawings had to be in the exact proportions and positions as the originals.
- Task 3 -- "Puzzles" (spatial scanning)
  Subjects were to solve line diagram puzzles by tracing over all the lines of the diagram with a continuous line (i.e., without tracing any line twice).

- Task 4 -- "Hidden Letters" (flexibility of closure)
  This task required subjects to search for capital letters outlined in dots and surrounded by random dot patterns.
- Task 5 -- "Inspection" (flexibility of closure)
  Subjects visually searched graphic designs for irregular lines, i.e., lines with breaks.
- Task 6 -- "Embedded Figures" (flexibility of closure)
  The task was to locate a particular figure which could be hidden within any of four patterns.
- Task 7 -- "Map Planning" (spatial scanning)
  The task was to identify the shortest route between two locations on a schematized map.
- Task 8 -- "Mazes" (spatial scanning)
  The task was to solve a series of mazes by tracing a path from the starting point to the goal.
- Task 9 -- "Altair Designs" (flexibility of closure)
  Subjects were presented with computer-generated graphics and were to locate specific designs hidden within the overall designs.

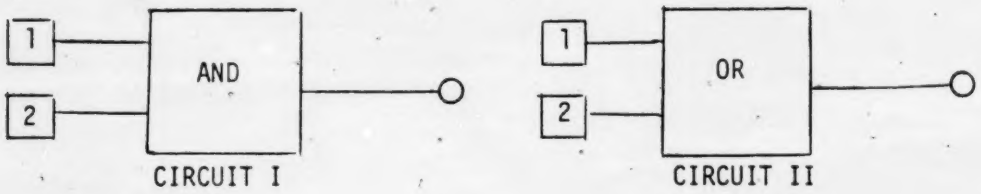
Ability Marker Tests

Two tests from the Kit of Factor-Referenced Cognitive Tests were used to assess subjects' ability levels. These were the "Hidden Patterns Test" for flexibility of closure, and "Choosing a Path" for spatial scanning. In the "Hidden Patterns Test," each item consisted of a geometrical pattern in which a single given configuration might or might not be embedded. The task was to mark each pattern in which the configuration occurs. In

the "Choosing a Path" test, each item consisted of a network of lines (as in an electrical circuit diagram) having many intersecting wires with five sets of terminals. The task was to trace the lines and to determine for which pair of terminals, marked S (start) and F (finish) there was a complete circuit. Both tests were speeded and scored in terms of number correct adjusted for guessing.

Troubleshooting Task

The troubleshooting task consisted of a series of problems in which subjects were required to locate malfunctions in diagrams of electrical circuits. The basic format was a digital-logic circuit in which the current flow at any point was determined by the preceding "AND" and "OR" logic gates. For example, in circuit 1 below, current can flow through the AND gate only if both switches 1 and 2 are depressed. In circuit 2,



only one switch is necessary to permit current through the OR gate. Each troubleshooting problem contained five such AND and OR gates.

Within each circuit diagram there was a single faulty wire or breakpoint which caused the current flow to be disrupted. The subject's task was to identify the location of that breakpoint by inserting a hypothetical probe (a "light bulb") at various locations (sockets) in the circuit and depressing the appropriate combination of switches to turn the light on.

If a particular light went on, then no break existed in that part of the circuit. On the other hand, if a light failed to go on, then one of the points lying on the path from the switch(es) to that light was faulty. A series of hypothetical probes (or tests) by the subject was required to isolate the actual breakpoint in each problem from the potential breakpoints.

Four basic circuit designs were used, each containing two AND gates and three OR gates in a different spatial configuration. For each basic circuit, three conditions of problem difficulty were created by varying the layout of the switches and wires while leaving the number and configuration of the logic gates unchanged. In the first level, the circuits appeared in an uncomplicated left-to-right, switch-to-gate-to-socket arrangement (Figure 1). In the second level, the basic overall left-to-right flow of current was maintained, but particular wires between switches and gates were interchanged so that proximal switches and gates were not necessarily connected, and wires sometimes intersected one another (Figure 2). In the third and most difficult level, locations of some of the switches were moved from the left side of the diagram, and the general left-to-right organization was disrupted (Figure 3). Manipulation of the problem difficulty variable resulted in twelve different problems (4 configurations x 3 levels of difficulty).

All problems were constructed with 5 AND/OR gates, 5 switches, and 16 possible breakpoints. Each of the problems so constructed was replicated once with a different breakpoint as the solution, thus resulting in a set of 24 problems.

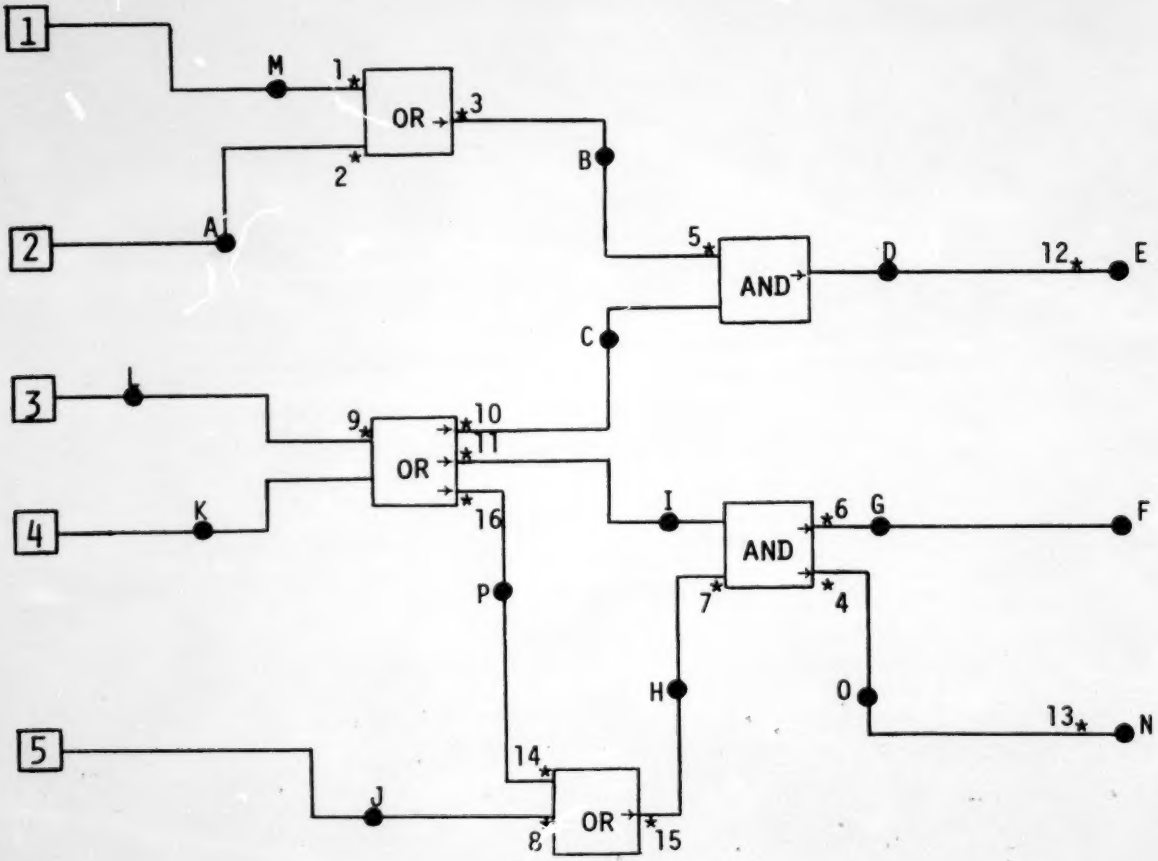


Figure 1. Example of troubleshooting problem at simplest level of problem difficulty. (Circles A-P respresent light sockets--i.e., locations where subject can place probe. Numbered stars are potential breakpoints.)

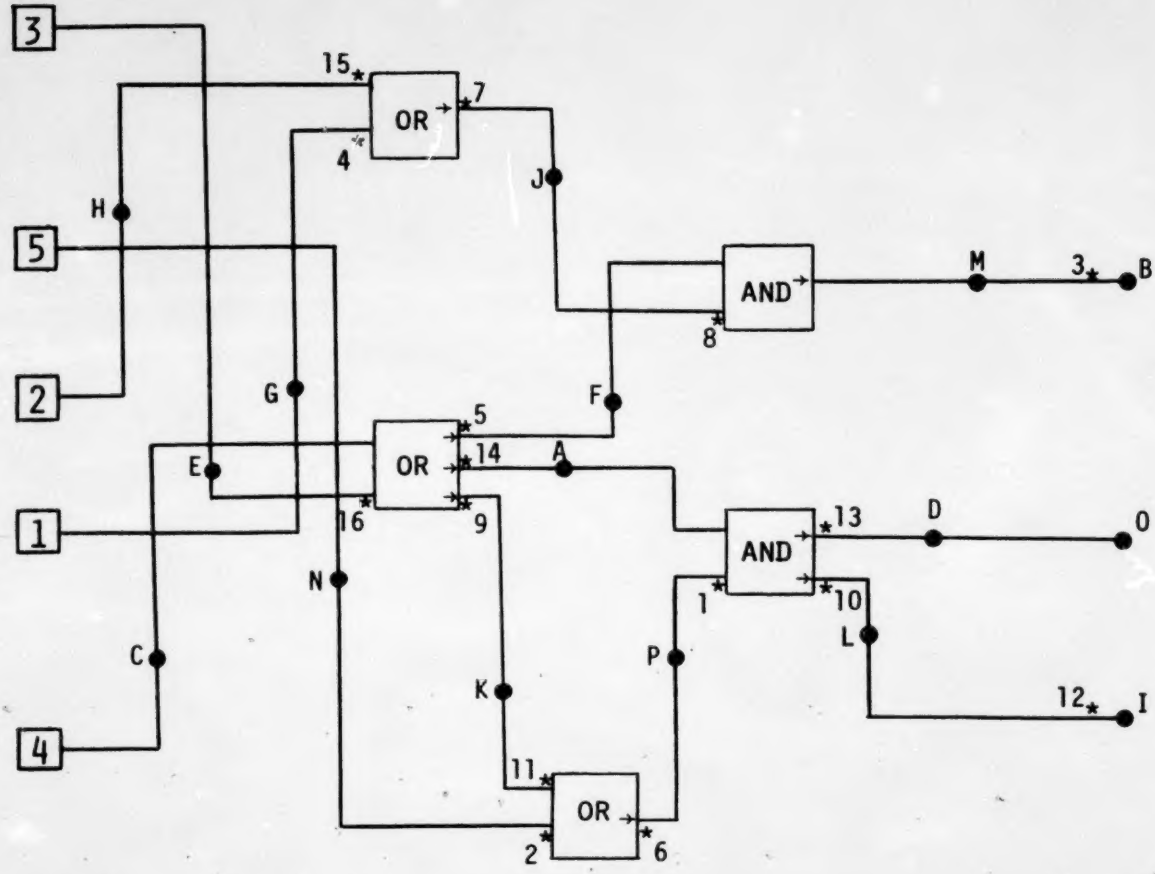


Figure 2. Example of troubleshooting problem at an intermediate level of problem difficulty.

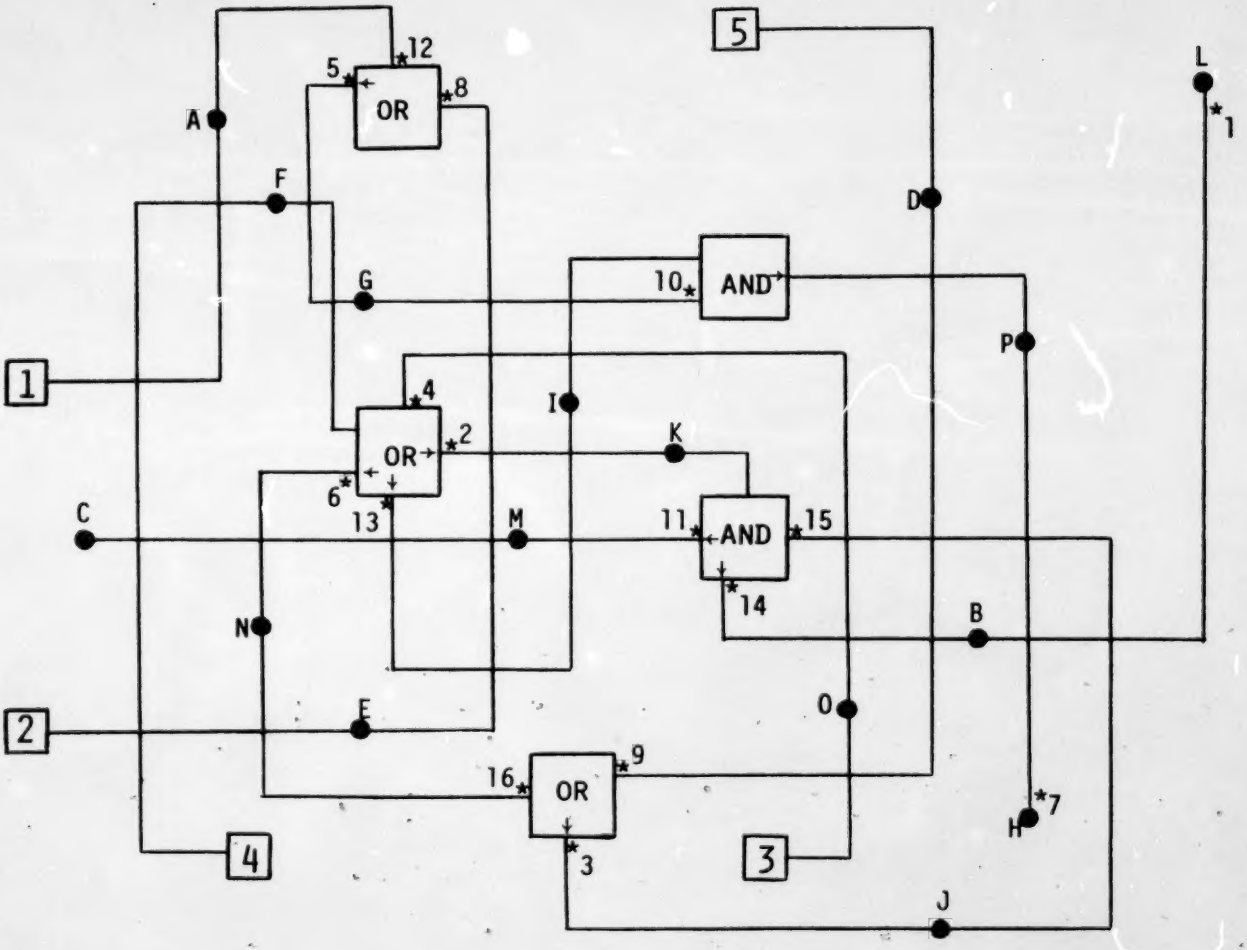


Figure 3. Example of troubleshooting problem at highest level of problem difficulty.

Experimental Design

Table 1 presents the experimental design of the study. There were five groups, each experiencing a different sequence of activities as described below. In Table 1, A is the criterion or transfer task (i.e., electronic troubleshooting), B is the set of materials selected to train the abilities of interest, and X is the designation for unrelated activity engaged in by a group of subjects in lieu of an experimental treatment. T_1 represents the administration of the two ability marker tests prior to training. T_2 represents the readministration of the tests subsequent to training.

Experimental groups (E_1 and E_2) received intensive ability training while control groups (C_1 and C_2) received no ability training. These four groups also performed on the criterion task. The design addressed two important questions: (1) Were the abilities trained? and (2) Did transfer occur?

The experimental groups differed only in that group E_1 received a pretest on the criterion task. The use of a pretest, in which several similar, but not identical, problems from the criterion task are administered prior to any training, permits the collection of baseline measures of criterion task performance. Scores on this pretest can then be used to adjust scores on the posttest in order to eliminate any bias in the posttest scores which may be due to initial performance differences between experimental and control groups on the criterion task. A potential disadvantage of such pretesting, of course, is that the pretest itself may provide some training or practice that positively transfers to the posttest situation. In order to account for this, Group E_2 was included.

TABLE 1

Experimental Design

Group	Day 1 Pretest	Days 2-4 Train	Day 5 Posttest	n
E_1	A	T_1 B T_2	A	(15)
C_1	A	X	A	(10)
E_2	X	T_1 B T_2	A	(15)
C_2	X	X	A	(10)
C_3		T_1 X T_2		(10)

X = No Activity

A = Criterion Task

B = Training Tasks

T = Marker Tests of Abilities

Comparisons on the posttest between E_1 and E_2 reveal any effect due to practice on the criterion task during the pretesting phase.

Group C_1 is a control group which did not receive any training. By comparing posttest performance for groups E_1 and C_1, the question of transfer is addressed. Group C_2 is a control group which received neither pretesting nor training. This group performed only on the criterion task. Performance on the posttest for the two control groups C_1 and C_2 can be compared to further assess the effect of practice during pretesting on the criterion task. Group C_3 received only the ability marker tests.

The question of whether the abilities were trained is addressed by comparing performance on T_1 and T_2 for the two experimental groups. If performance on T_2 is substantially greater than T_1 in each of these groups, and if Group C_3 does not demonstrate a significant improvement across administrations, then it can be concluded that success has been realized in training the abilities.

The need for ability marker tests requires some explanation. In most transfer research, the effect of training is assumed to be reflected in the posttest comparisons between experimental and control groups on the criterion task. In the present effort, it is possible for criterion task performance to be unaffected by training, despite having successfully trained the abilities under study. This is true because the criterion task requires (for successful performance) more than the two abilities under investigation--and the enhanced abilities may not contribute sufficiently to troubleshooting performance to result in improved proficiency. To identify whether or not transfer findings are specifically due (at least

in part) to the enhancement of the two abilities being investigated, marker tests which are "pure" measures of those abilities are required.

The ability marker tests also allowed for a partitioning of each of the experimental groups into high and low initial ability subjects. This permitted separate analyses of the results to be carried out in the event transfer of training was contingent upon the ability level subjects brought to the experimental situation.

Procedure

Subjects were randomly assigned to the five groups and participated in one experimental session daily for up to five consecutive days. In the first session (pretest) the troubleshooting task was administered; sessions two, three, and four consisted of ability training and administration of the ability marker tests preceding and following training; the final session (posttest) consisted of the administration of the troubleshooting task using a different and larger set of problems. Subjects were individually tested on the troubleshooting task, and received training and were administered the ability marker tests in groups of five.

On first reporting to the laboratory, subjects were briefed on the general nature of the study and the types of tasks they would be performing. They were informed that they could earn additional money in excess of the amount they were guaranteed for participating in the study, and that this amount was dependent upon the quality of their performance.

Subjects were next instructed in the concepts and mechanics of troubleshooting. This included presentation and discussion of six sample problems graded in difficulty. Subjects were told that each problem would have one

breakpoint and that their task was to discover this breakpoint. The instructions emphasized working as quickly as possible and solving for the breakpoint in the fewest possible tests. In order to encourage both speed and accuracy, a point system based on these two factors was devised. Subjects were told that they would earn 150 points for each problem correctly solved, and that 10 points would be subtracted for each test made, and five points for each minute elapsed until a problem was solved. No points would be awarded for an incorrect solution. They were informed that the total accumulated points would be converted to monetary payoff at the end of the experiment.

In order to reduce individual differences in strategy, subjects were told that efficient troubleshooters attempt to eliminate about half the remaining breakpoints from consideration with each test they make. Subjects were given a pad of paper and encouraged to use it in keeping track of tests performed and points eliminated, so that the memory factor in task performance would be minimized. These procedural steps were taken with the intent of reducing variance in performance due to the abilities of induction, syllogistic reasoning, and memory, identified in the earlier study (Rose et al., 1974).

Following the instructional session, subjects were administered the troubleshooting pretest. The pretest consisted of two practice problems plus six problems which had been randomly drawn from the twenty-four generated. Two problems of each of three difficulty levels were included. The order of presentation was randomized, with the limitation that no two problems with circuits having the same basic design could occur consecutively. Problem presentation order was the same for all subjects.

The subject made tests of the circuit by indicating the switch(es) he wanted to depress and the letter of the light he wished to probe. He was given immediate verbal feedback as to whether or not the light went on. The subject continued to formulate tests and receive feedback until he had determined the location of the breakpoint. Subjects were told whether or not they had correctly solved the problem and, if incorrect, were given the correct answer. Subjects were allowed an unlimited number of tests per problem and could make tests at their own pace. However, a time limit of 15 minutes per problem was set, so that if a solution was not arrived at within that time, the problem was terminated and scored as incorrect. Instructions and pretesting required approximately two hours.

The second, third, and fourth days consisted of the training phase of the experiment. Subjects participated in a single five-hour session on each of these days.

On the second day, the ability marker tests for flexibility of closure and spatial scanning were administered. Subjects were introduced to the training phase of the experiment and instructed that they would be performing a series of tasks over the next three days which would involve certain visual perceptual abilities. The abilities were described and examples of real-life activities requiring their use were given. Subjects earned incentive pay on the basis of how close they came to the maximum possible score on the training tasks.

Specific task instructions were read by the Experimenter and a sample problem was shown and explained prior to each training task. Tasks 1-4 were administered on the second day; tasks 5-9 on the third day. On the

fourth day, tasks 2, 3, 7, 8, and 9 were repeated. Tasks were self-administered; however, subjects were encouraged to ask questions about anything they didn't understand at any time during the task. Feedback was built into each training package and consisted of descriptions and/or diagrams of correct solutions which were displayed immediately following each page of problems. Subjects were instructed to complete a page of problems, then to compare their work with the correct solutions before continuing with the task. The single exception to this procedure was task 7, a search task, wherein feedback was received after the entire task was completed.

Subjects worked at their own pace through each task. Because training occurred in a group situation, subjects were required to wait until everyone in the group had completed the previous task before proceeding to the next one. Tasks varied in terms of average completion time from ten minutes to one and one-half hours. The tasks were self-scored, enabling subjects to determine how well they did in comparison with the maximum possible score. Subjects were carefully monitored to insure accurate scoring. At the end of the last training session, both ability marker tests were readministered.

On day 5 (the final session), subjects returned for the troubleshooting posttest. Instructions were repeated in a slightly abbreviated form, followed by the two practice problems used in the pretest. Each subject was then individually administered eighteen posttest problems, representing six problems at each level of difficulty. As in the pretest, the order of presentation was randomized and was identical for all subjects. The

posttest session lasted approximately four hours. At the end of the session, the amount of incentive pay earned by the subject for all tasks was computed and added to the fee guaranteed for participating in the experiment. Subjects were paid and questions about the nature and purpose of the study were answered at that time.

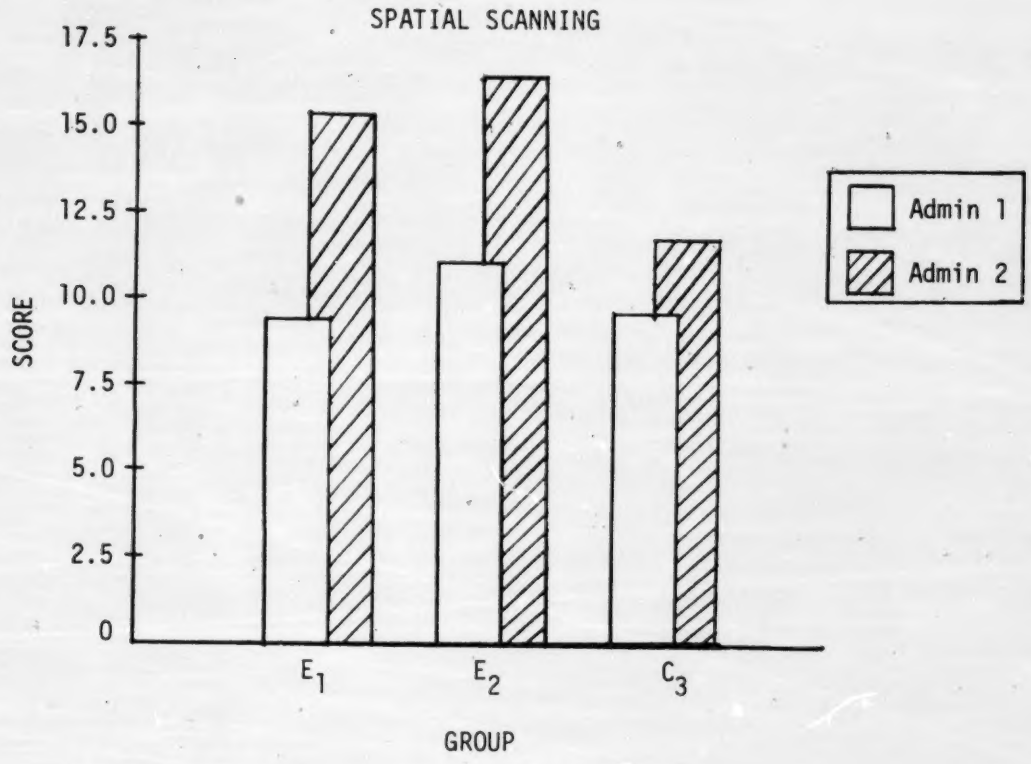
The preceding described the treatment of subjects assigned to Group E_1. Subjects assigned to Group E_2 were treated in an identical fashion to Group E_1, except that the first day's session (pretest) was omitted. Subjects in Group C_1 received both the pretest and posttest, but did not receive ability training. Subjects in Group C_2 received only the posttest and those in Group C_3 received only the ability market tests. A total of sixty subjects were tested according to the design in Table 1.

RESULTS

Analyses were carried out on the scores obtained from the ability marker tests and the troubleshooting task. Performance measures for the troubleshooting task included accuracy, number of tests to solution, number of erroneous tests (those for which there was no pathway connecting the switch and light, or in which current could not flow through the AND/OR gates), and time to solution for each problem.

Mean scores on both administrations of the ability market tests were contrasted for the groups receiving training (E_1 and E_2) and the untrained control group (C_3) in order to determine whether the training regimen resulted in improvement of the abilities being trained. The results indicated that spatial scanning was successfully trained, but that flexibility of closure was not. Figure 4 shows the mean scores for the several groups who were given the ability tests. On the spatial scanning test, the two trained groups showed a significant improvement between administrations ($t\ (28) = 4.43$ and 2.34, $p < .01$, for Groups E_1 and E_2, respectively), while the untrained group showed no statistically significant improvement. On the flexibility of closure test, however, both trained and untrained groups showed significant improvement across the two administrations of the ability test ($t\ (28) = 3.71$, $t\ (26) = 5.28$, and $t\ (17) = 3.71$, $p < .01$, for Groups E_1, E_2, and C_3, respectively). Since the untrained control group showed significant improvement between test administrations, we cannot conclude that the improvement in the experimental groups was due to training.

A one between-subject, two within-subject analysis of variance was carried out on the data obtained from the troubleshooting posttest. The



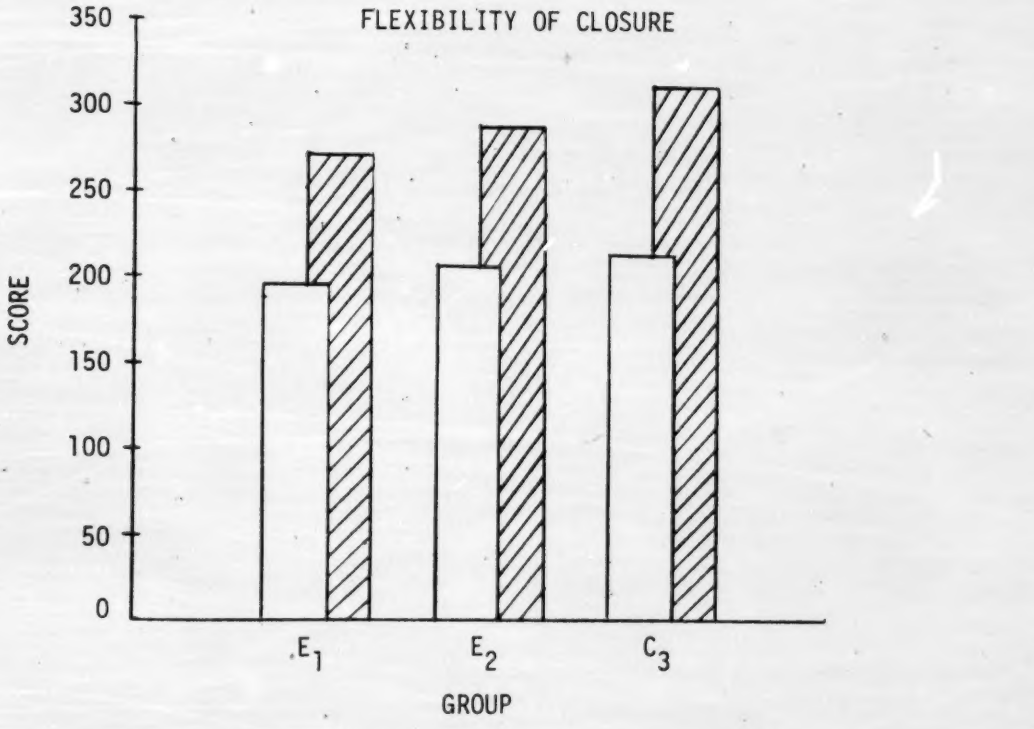


Figure 4. Mean scores on ability marker tests.

between-subject variable was groups. The within-subject variables were blocks of trials and problem difficulty. There were four groups and three blocks of six problems, each block containing problems of three levels of difficulty. Analyses were carried out for each of the four measures of performance defined earlier.

Of principal importance were the main effect of groups and the group x trial blocks and group x problem difficulty interaction effects. Although we were clearly concerned with differences among the trained and untrained groups, we were equally interested in whether the influence of training varied as a function of practice on and difficulty of the task.

The results indicated that the only effects of interest which were statistically reliable were for the time to solution performance measures. Here, the main effect of groups and the groups x problem difficulty interaction were significant ($F(3, 46) = 5.19$ and $F(6, 92) = 3.30$, $p < .01$, respectively). The significant main effect of groups was evaluated using t-tests to make comparisons among the means. The results indicated that there were no differences between the trained (E_1 and E_2) and untrained (C_1 and C_2) groups, but that time to solution was significantly less for pretested groups (E_1 and C_1) than for groups not given a troubleshooting pretest (E_2 and C_2). Thus, while training had no impact upon performance on the troubleshooting task, prior practice on a pretest improved subsequent posttest time to solution. Table 2 presents the group means for each of the dependent variables.

The group x problem difficulty interaction is depicted in Figure 5. Contrasts among means indicated that E_1 solved problems more quickly than

TABLE 2

Troubleshooting Group Means

Performance Measure	Group				Grand Mean
	E_1	C_1	E_2	C_2	
Accuracy	.88	.88	.90	.89	.89
No. of Tests	5.13	5.17	4.85	5.55	5.14
No. Erroneous Tests	.22	.24	.22	.24	.23
Time to Solution	177.68	179.71	242.04	267.43	215.35

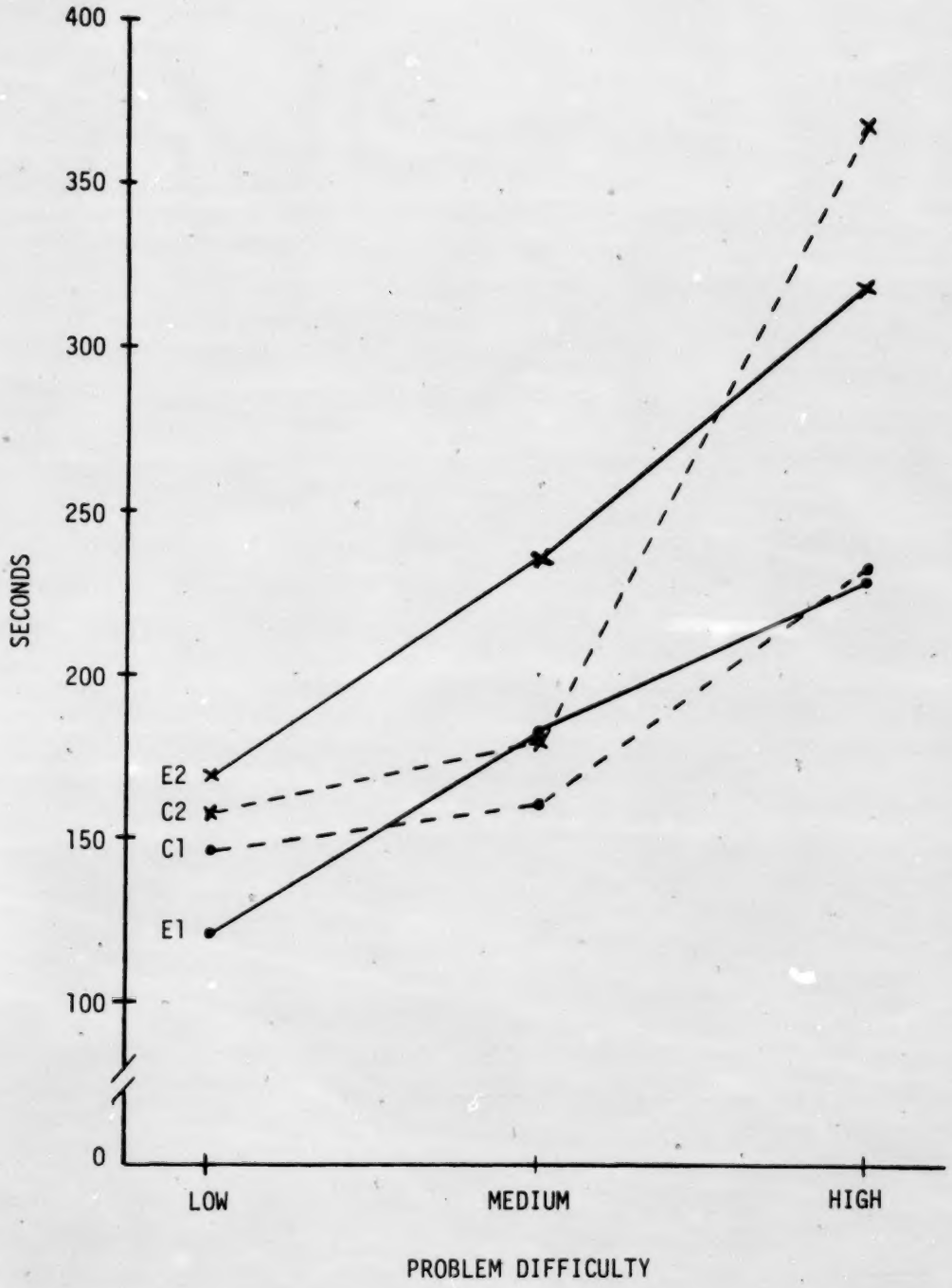


Figure 5. Mean time to problem solution as a function of group and problem difficulty.

E_2 under all levels of problem difficulty and that C_1 was better than C_2 only for the most difficult set of problems.

Although there was little technical interest in other findings from the analyses of variance, it should be noted that the main effects of trial block were significant for each performance measure. Essentially, performance on the last two blocks of problems was nearly identical and was significantly superior to performance on the first trial block. The main effect of problem difficulty was also significant for all performance measures except number of tests. Performance was consistently poorer as problem difficulty increased.

Although contrasts among trained and untrained groups on posttest performance (E_1 vs. C_1 and E_2 vs. C_2) failed to demonstrate any significant effect of training, it was premature to conclude that training did not impact upon posttest performance. The lack of a training effect could have been due to initial differences among groups in their skill at solving troubleshooting problems despite the random assignment of subjects to groups. A more sensitive test of the transfer effect, therefore, was carried out on the data from Groups E_1 and C_1 using analyses of covariance. The analyses of covariance had the effect of adjusting posttest scores for individual differences on the pretest (i.e., essentially matching the groups on the basis of the pretest). The covariate was the mean pretest score for each subject on each of the four dependent variables.

The analyses of covariance failed to reveal any significant effects of interest. Groups E_1 and C_1 (both pretested, but only the former trained)

did not differ on any measure. This result was consistent with the outcome of the analyses of variance. There were no significant group x trial block or group x problem difficulty interactions. Overall, transfer (computed as E-C/C) ranged from -3.4% to 14.3% across the four measures of troubleshooting performance. Figure 6 shows the mean scores for the two pretested groups on each block of problems for each of the dependent variables evaluated. Averaged over all subjects in the two groups, adjusted mean accuracy was 87%; the number of tests to solution was 5.15; the number of erroneous tests made was .22; and time to problem solution was 177 seconds.

On the assumption that ability training may be effective only for individuals who bring a relatively low level of the ability to the task, additional analyses were carried out. Subjects in Group E_1 were partitioned into the five highest and five lowest scorers on the first administration of the spatial scanning test. A similar separate partitioning based upon the flexibility of closure test was also carried out. Performance of each subgroup was compared to that of the untrained control group. Analyses of covariance were used on this reduced sample with mean pretest scores as the covariate. These analyses were carried out only on the number of tests and time to solution measures, since earlier analyses showed there was little variability among subjects in terms of accuracy and number of erroneous tests.

The results indicated no differences between either the high ability or low ability subgroups of trained subjects and the untrained control group for the spatial scanning or flexibility of closure breakdowns.

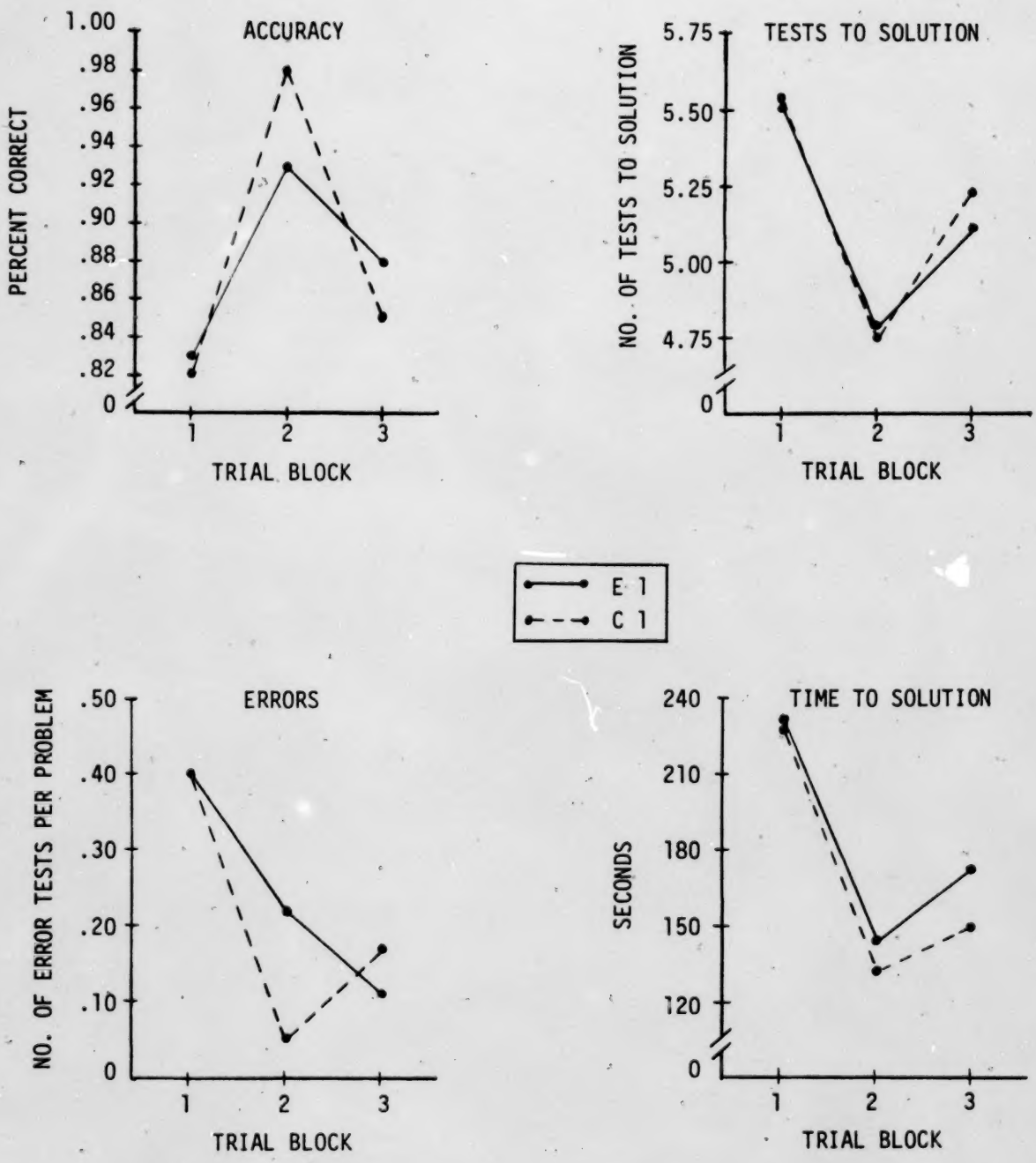


Figure 6. Adjusted mean performance of trained groups and untrained groups as a function of trial blocks.

No evidence of transfer of training was revealed on either high or low ability groups. The only significant result was that subjects classified as low on spatial scanning required more time to solution than subjects classified as high.

DISCUSSION

Extensive training of two abilities involved in an electronic fault-finding task (troubleshooting) resulted in significant enhancement of spatial scanning but not of flexibility of closure as measured by standard ability tests administered before and after training. There was no evidence that performance on the troubleshooting task was improved significantly as a result of training (i.e., there was no transfer of training).

The measures of training effectiveness were the "Hidden Patterns Test" for flexibility of closure and "Choosing a Path" for spatial scanning. These tests, taken from the Kit of Factor-Referenced Cognitive Tests, are generally accepted as valid measures of the abilities under study. There were marked improvements in scores between administrations of the flexibility of closure marker test for the untrained control group (C_3) as well as for the trained groups (E_1 and E_2). The improvement in group C_3 may have been due to the ease and highly speeded nature of the test. The combination of simplicity (there were rarely any incorrect answers) and speed could have resulted in improvement across administrations owing simply to a learning to learn phenomenon. Thus, it is possible that training of flexibility of closure was effective but that it went undetected because the test instrument used was not sufficiently complex to be sensitive to improvement.

The training regimen adopted in this study was based upon extensive self-paced practice with feedback using a broad array of tasks having a wide range of difficulty and known to require either flexibility of closure or spatial scanning. Fourteen hours of training were given over a three-day period. Clearly, there were other possible training approaches which

might have had an impact on criterion task performance. For example, training could have been made even more extensive and distributed over a longer period of time in order to increase its potential effectiveness. For practical reasons this could not be carried out in the present study; the logistics of having our subjects return for additional sessions over more days or weeks could not be accommodated in a cost effective fashion. A captive population would be required to engineer such an extended training paradigm. The amount of training required to improve an ability is a research issue which has not been addressed in previous research and could not be in the present study. Consequently, the choice of time parameters in the training procedure was somewhat arbitrary, guided largely by practical constraints.

In addition to a variety of modifications in the phasing and amount of training provided by our approach, there are other approaches which could have been adopted. We could have identified and then trained the strategies which result in successful performance on tasks having similar ability requirements. Alternately, we could have obtained data on specific behaviors involved in the criterion task (which were relevant to the two abilities of interest) and developed a training paradigm around those behaviors. We know of no basis for choosing among these varied approaches or other possible training paradigms; and it was beyond the scope of this effort to evaluate the alternatives empirically.

A careful examination of the relationship between the abilities required for successful performance on the criterion task and the abilities which were trained may offer some explanation for the failure to find significant positive transfer of training. It will be recalled that

Rose et al. (1974) found that spatial scanning and flexibility of closure together were the dominant abilities in a troubleshooting task identical to the one used in the present study. However, the separate contribution of each of these two abilities to troubleshooting performance could not be isolated. It should also be recalled that there were other abilities involved in this task, including memory, induction, and reasoning. While flexibility of closure and spatial scanning jointly had the highest factor loading of any other ability on several indices of troubleshooting performance, the other abilities combined accounted for 70% of the variance in performance. Therefore, failure to obtain transfer of training may reflect the fact that flexibility of closure and spatial scanning did not account for a sufficient proportion of the ability requirements of the task. Despite the fact that one of those abilities (spatial scanning) was enhanced through training, this enhancement did not substantially contribute to the quality of subsequent troubleshooting performance. It is important to note that speculations concerning the reasons transfer of training did not occur must include the possibility that ability enhancement simply does not transfer to dissimilar tasks requiring the same abilities.

In order to assess the degree to which the troubleshooting task related to the abilities trained in the present study, correlation coefficients were computed between the scores on the first administration of the ability marker test and mean troubleshooting scores on the posttest for all trained subjects. Number of points earned was used as the measure of troubleshooting performance, since this index was based upon both speed and accuracy. The average correlations were .26 and .51 for flexibility

of closure and spatial scanning, respectively; the latter correlation was significantly different from zero.

The results of the present study were not conclusive. A follow-up study is planned which will attempt to train a single ability (spatial visualization) and evaluate transfer on three different criterion tasks which involve this ability to varying degrees. For one of these criterion tasks, visualization is the only required ability. Consequently, a more precise evaluation of the issue of transfer of ability training will be possible.

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APPENDIX

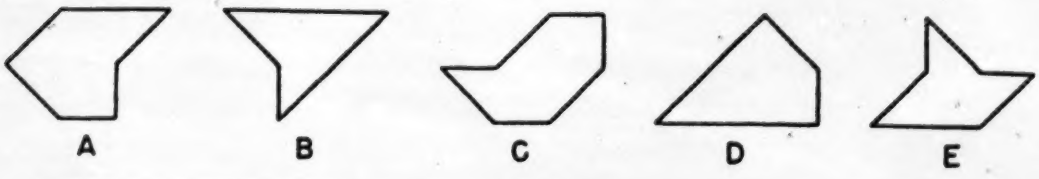
EXAMPLES OF TRAINING TASKS

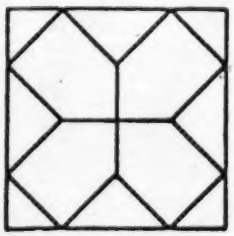
TASK 1 -- Hidden Figures (F.C.)

Find one of the figures A-E in each of the designs.

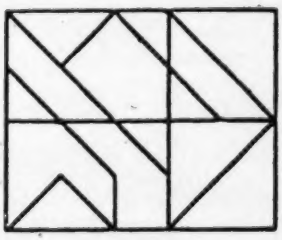
Circle the appropriate letter beneath the design; then outline the figure within the design.

Figures are <u>always</u> right side up and the same size as shown above the designs. There is <u>one</u> and <u>only one</u> figure in each design.

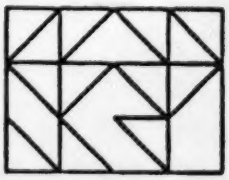


1. 

A B C D E

2. 

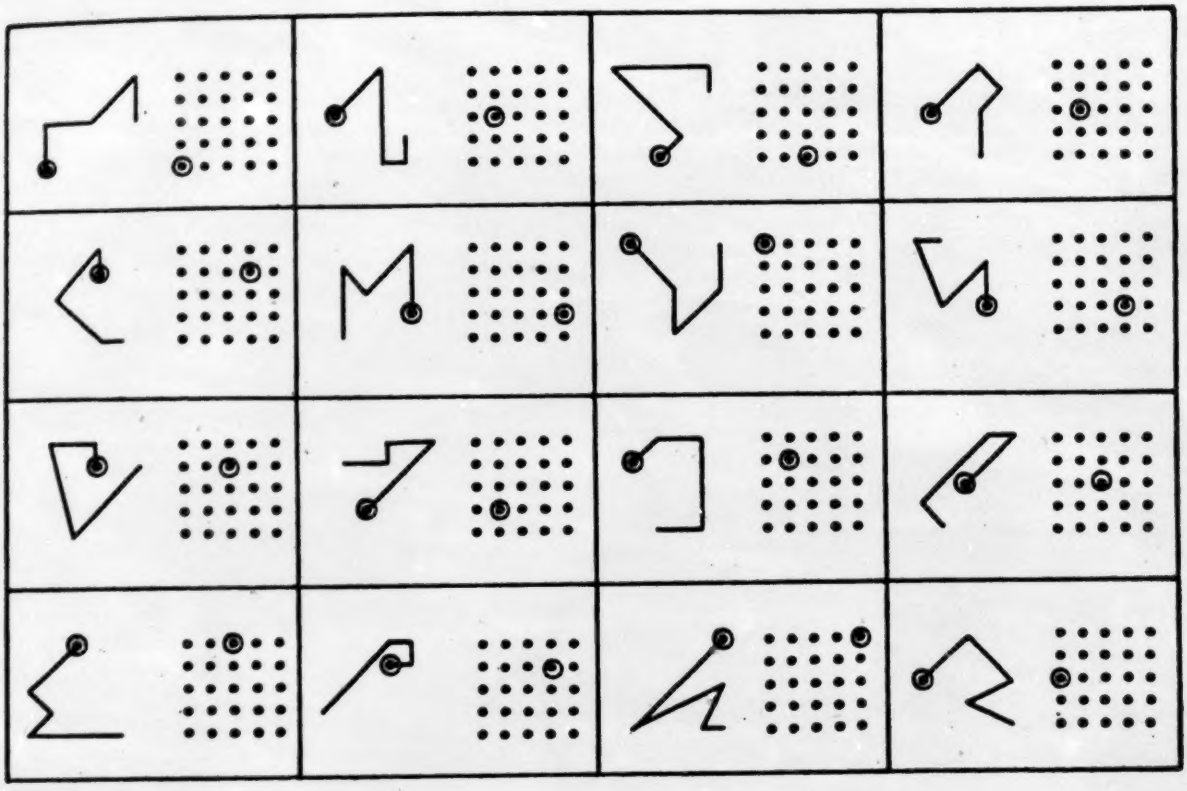
A B C D E

3. 

A B C D E

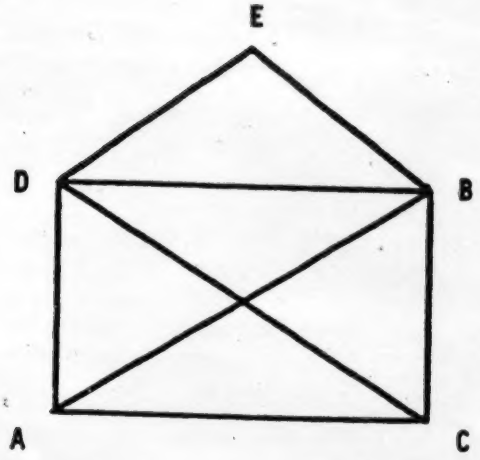
TASK 2 -- Copying (F.C.)

Copy each pattern in the dotted space to the right of it. Begin at the circled dot. You may erase.



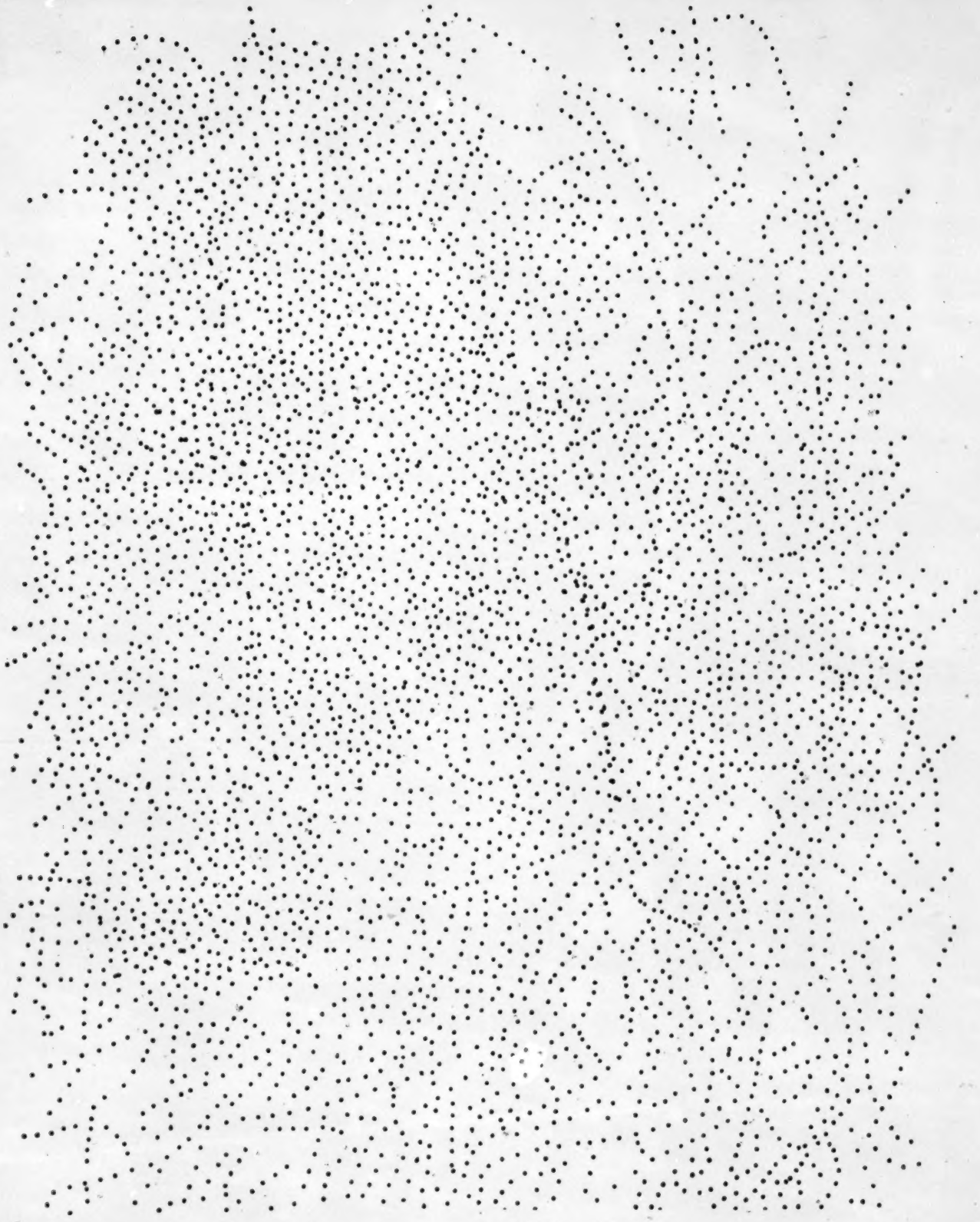
TASK 3 -- Puzzles (S.S.)

Trace over all the lines of the diagram without tracing any line twice and without repositioning your pencil on the diagram.



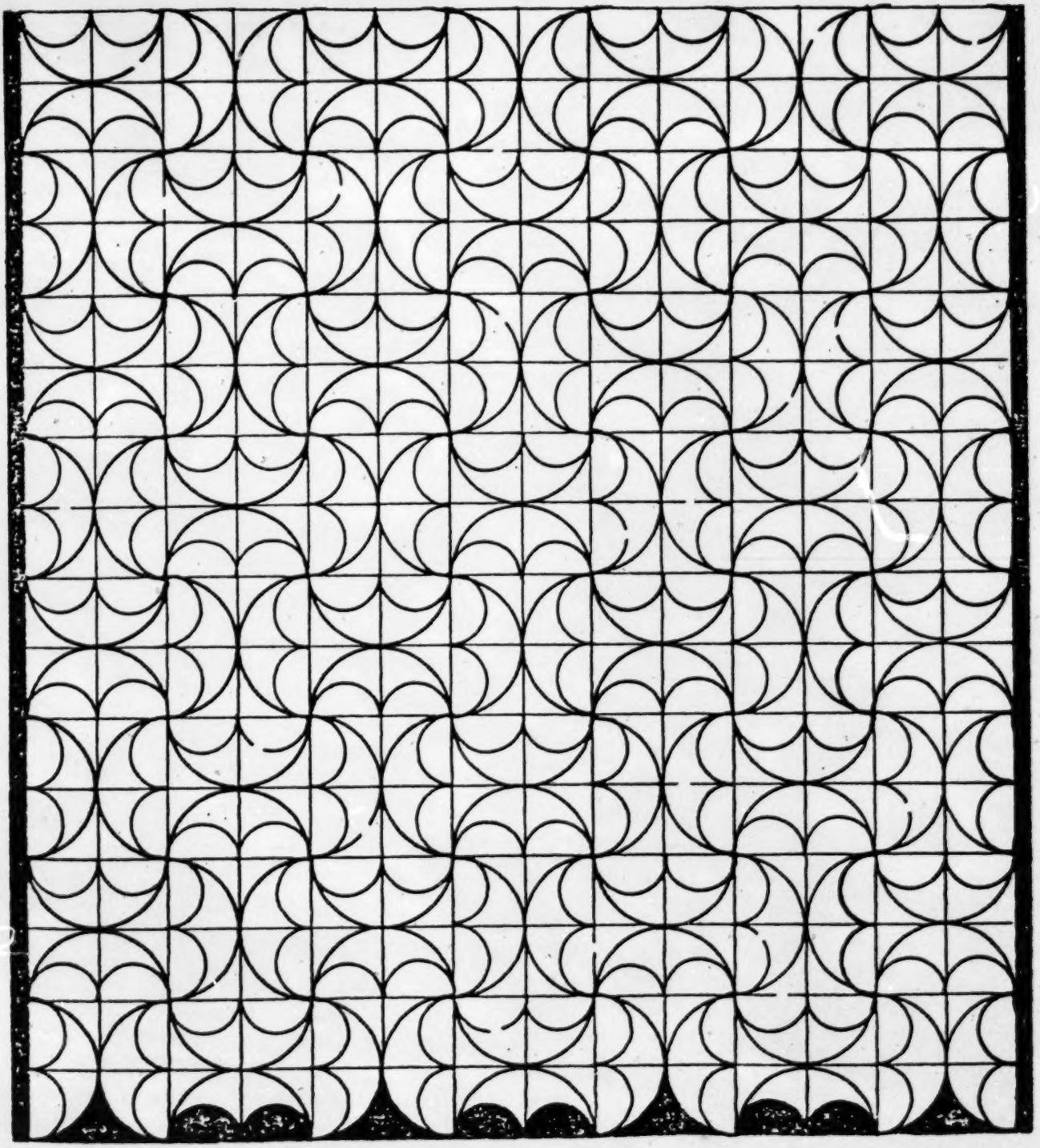
TASK 4 -- Hidden Letters (F.C.)

Find the letter "H" in the dot pattern below.



TASK 5 -- Inspection (F.C.)

Locate and circle as many breaks in the lines as you can find.



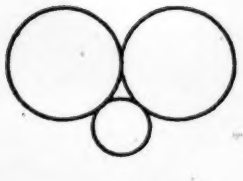
TASK 6 -- Embedded Figures (F.C.)

Put a "✓" under each design in which the figure on the left is hidden. Then darken the outline of the figure in the design.

The figure may appear in any, all, or none of the 4 designs.

The figure is always right side up and the same size in the designs.

1.



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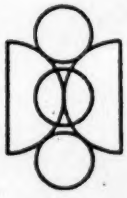

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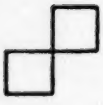
2. 

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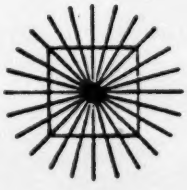

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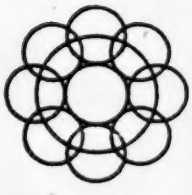

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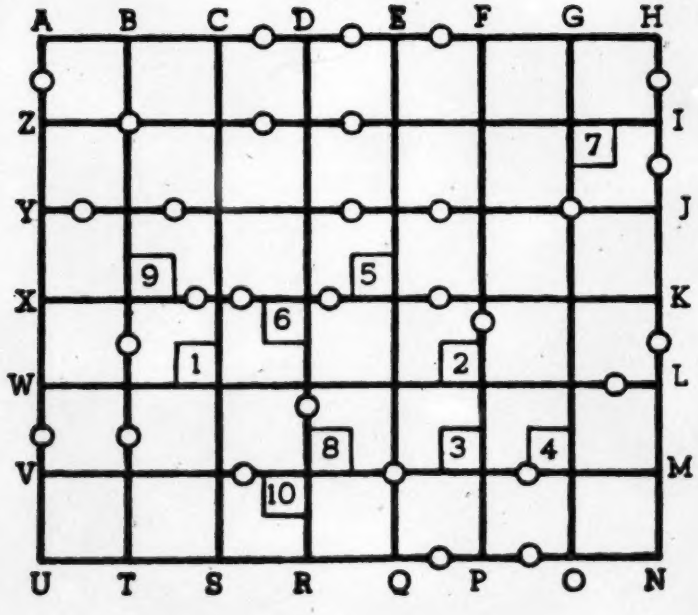
TASK 7 -- Map Planning (S.S.)

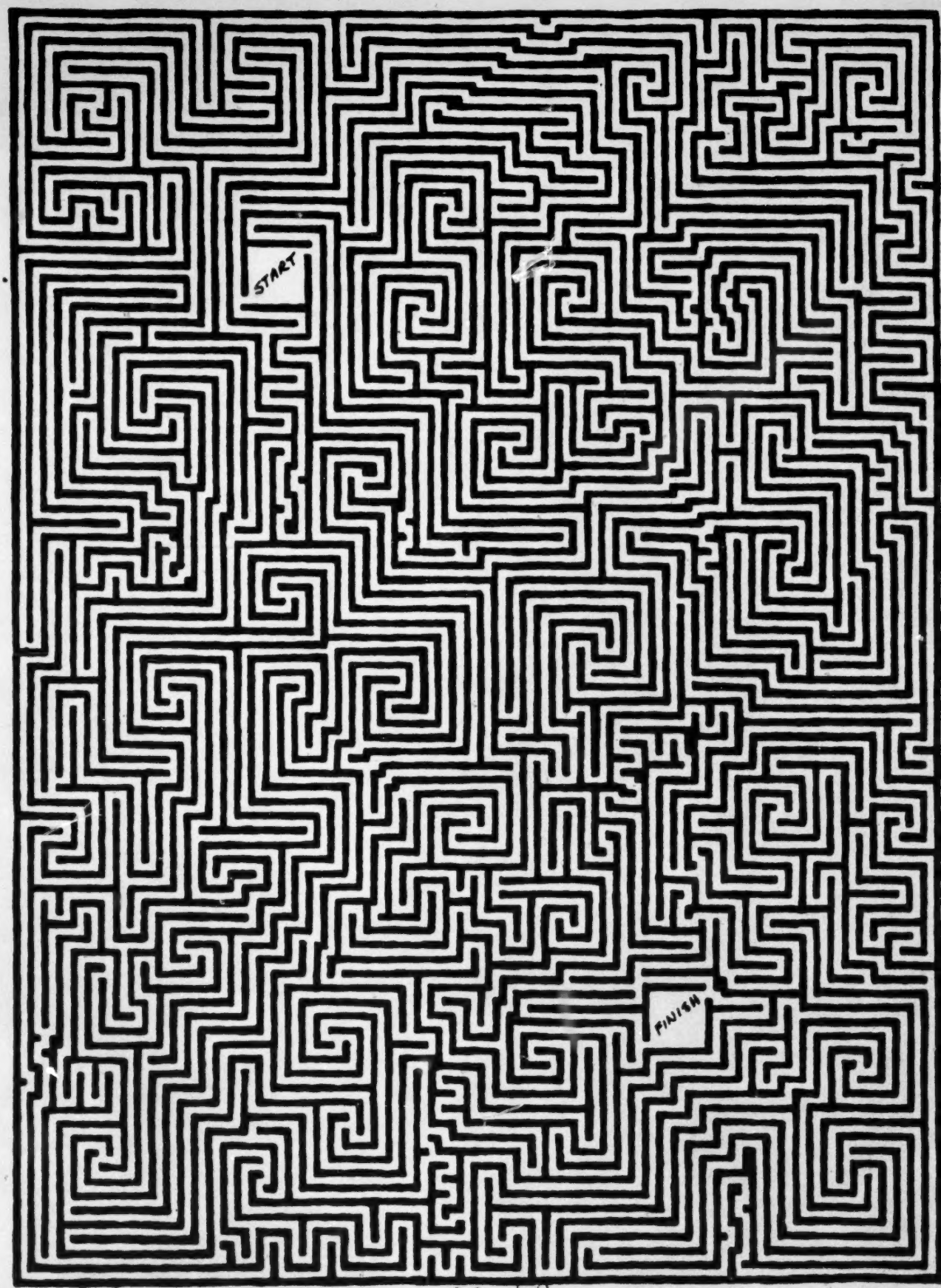
Find the shortest route between the points listed at the right side of the map. You can not pass where there are circles. The numbered squares are buildings. The number of the building passed is your answer.

The shortest route will always pass along the side of one and only one of the numbered buildings.

A building is not considered as having been passed if a route passes only a corner and not a side.



The shortest route from:	Passes building:
1. A to Z	_____
2. E to S	_____
3. P to J	_____
4. V to K	_____
5. O to F	_____
6. G to M	_____
7. D to Q	_____
8. F to T	_____

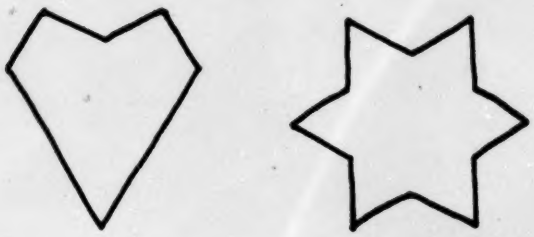

START
FINISH

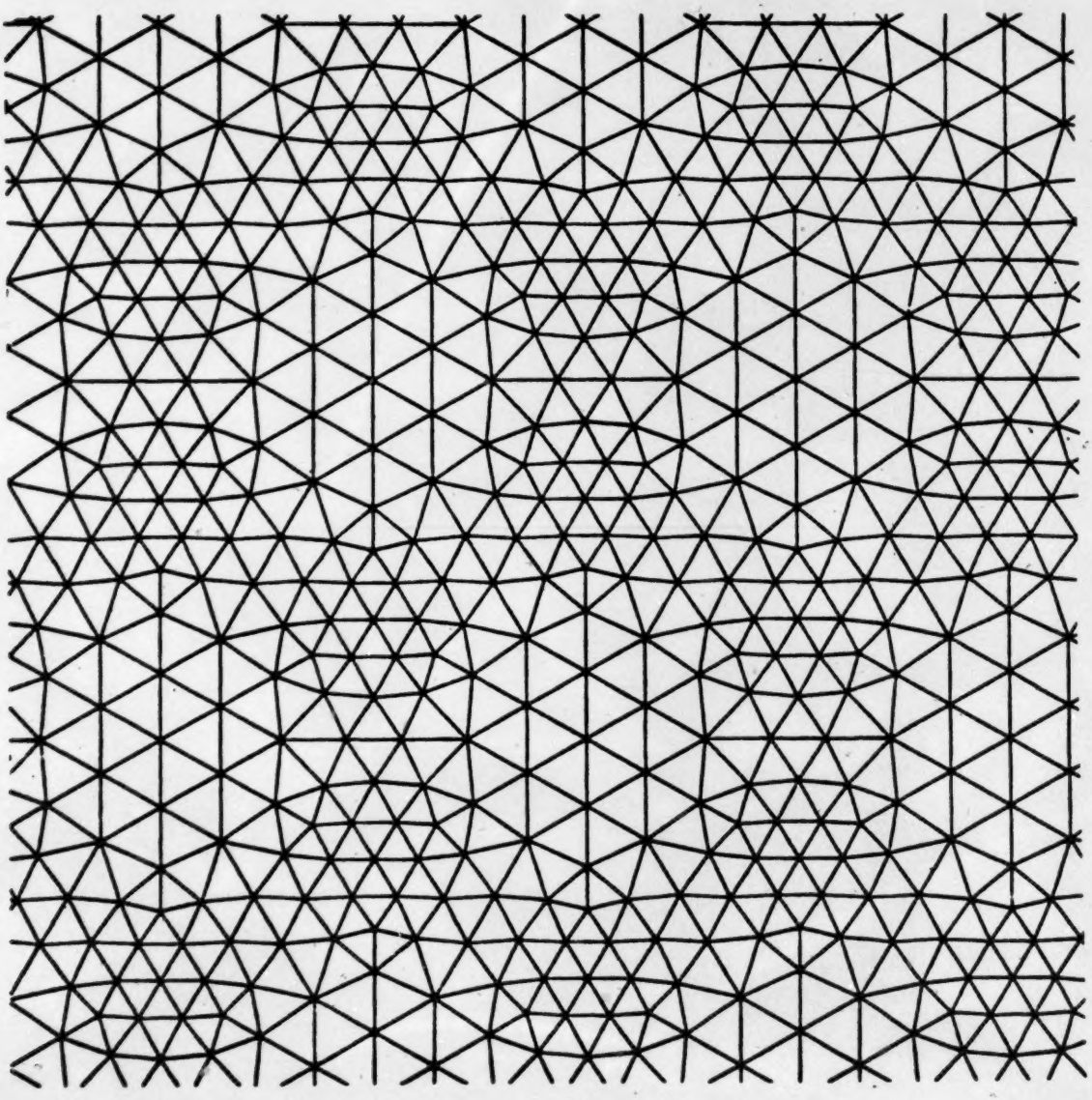
TASK 9 -- Altair Designs (F.C.)

Locate these shapes in the numbered designs and outline them in pencil.

DESIGN #2

(14 Items)





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